STAR Experimental Highlights

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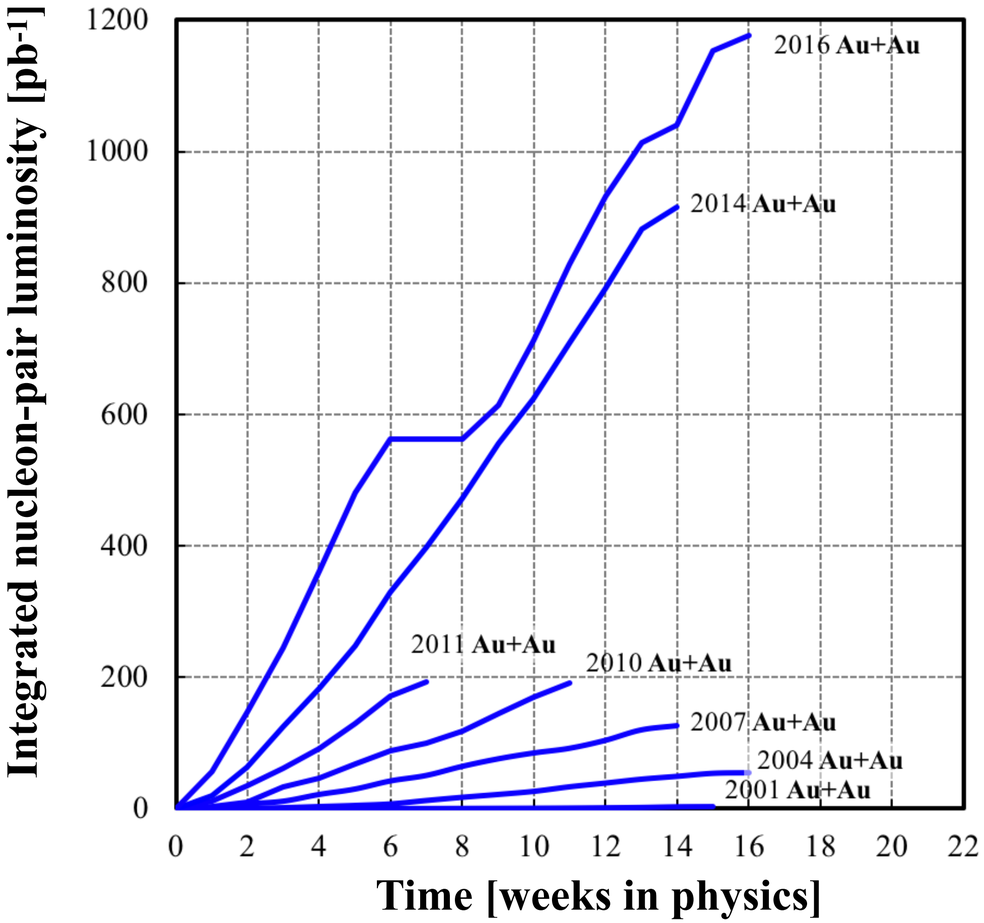
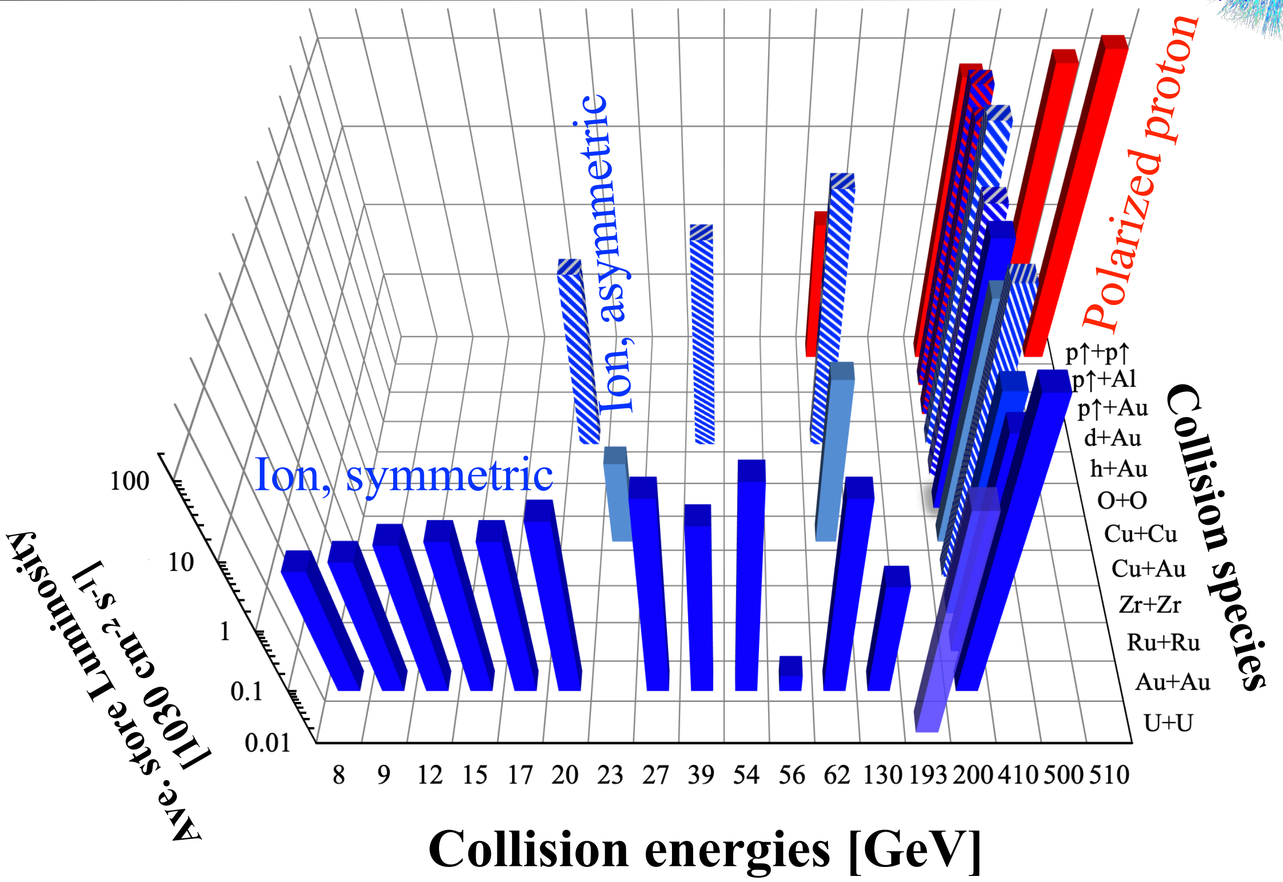
(for the STAR collaboration)

Germany
26 - 31 March 2023

Supported in part by
U.S. DEPARTMENT OF ENERGY

RHIC energies, collision species and luminosity

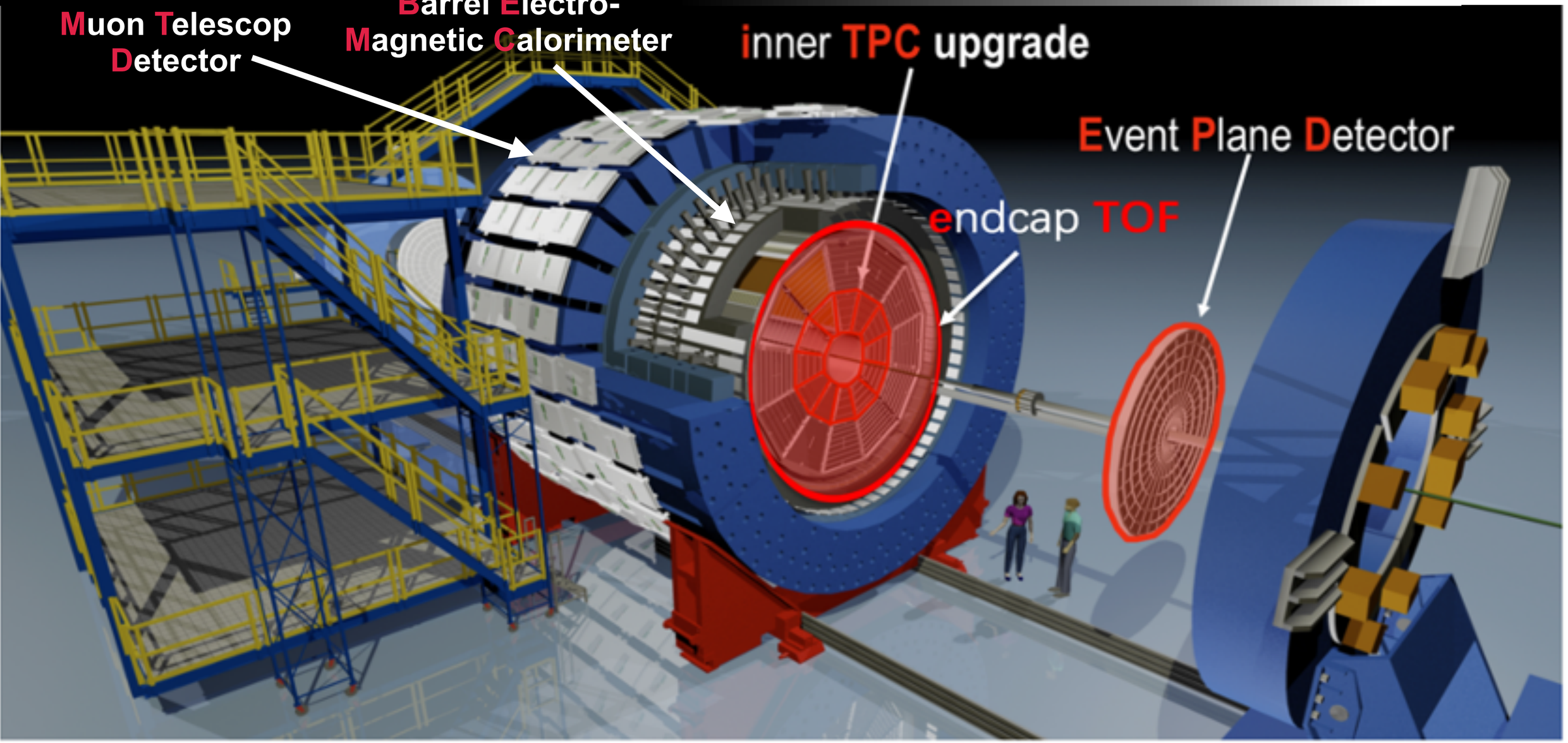




p+p, Ru+Ru, Zr+Zr and Au+Au data are presented at this conference

- Increased luminosity improves the precision of our measurements
- Different collision species allow to study the hot QCD medium at different conditions

STAR detector



STAR highlights

1. **Probing fundamental QCD: theory vs. reality**

   Energy-energy correlations and jet substructure

2. **What do hard probes tell us about QGP?**

   System size dependence of jet and heavy-flavor production and flow

   Different manifestations of jet-medium interaction and their consequences

7 parallel talks + 3 posters presentations

1. **Probing fundamental QCD: theory vs reality**

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2. **What do hard probes tell us about QGP?**

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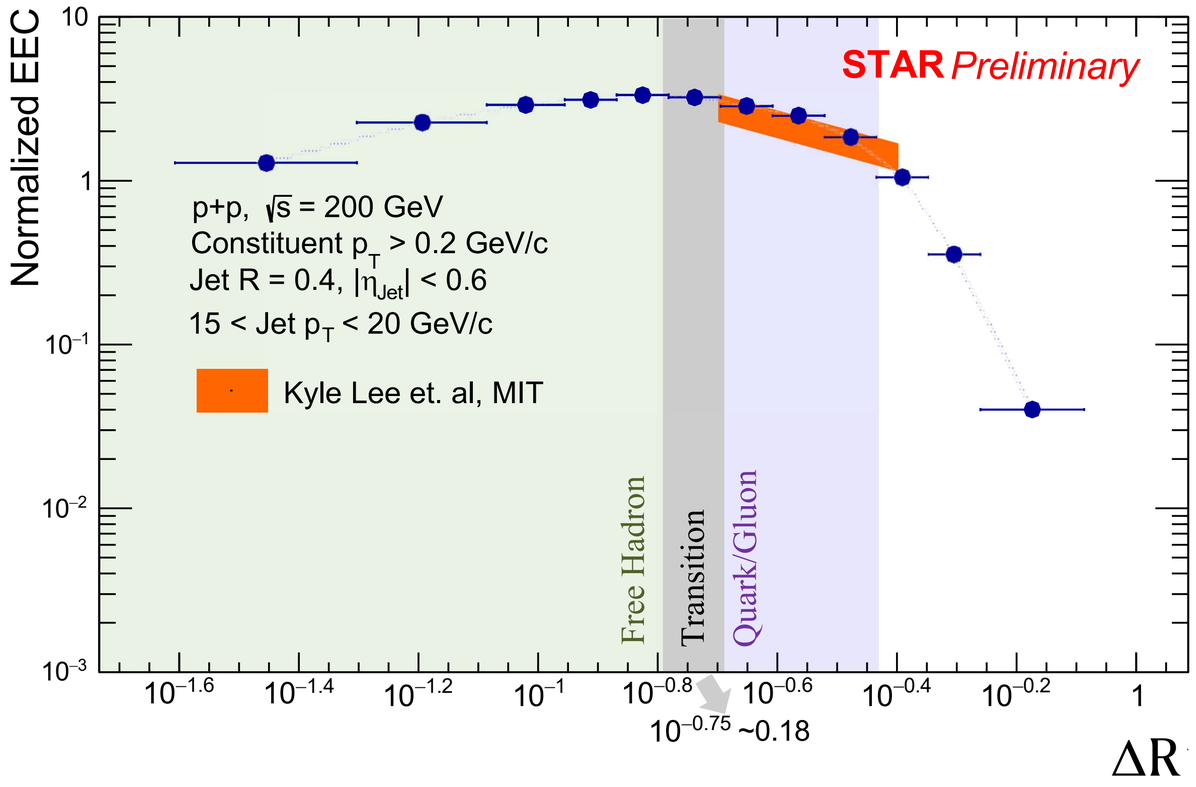
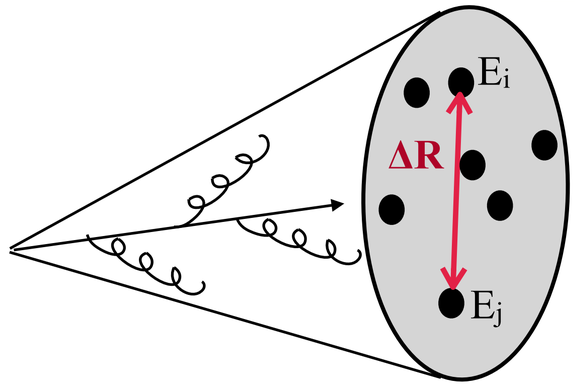
Energy-energy correlation



"field theory faces reality"

arXiv:2205.03414 , 2209.11236

Andrew Tamis
29 Mar, 11.30



Correlation functions of energy flow operators

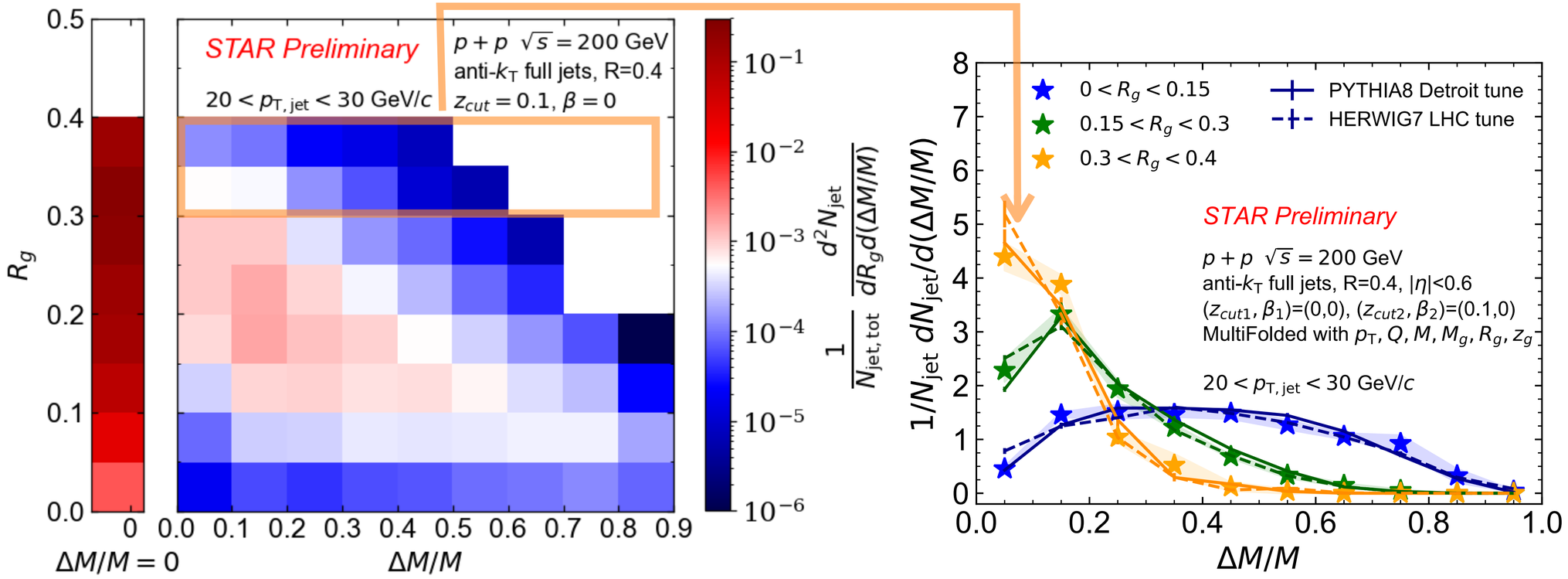
$$\text{Normalized EEC} = \frac{1}{\sum_{\text{jets}} \sum_{i \neq j} \frac{E_i E_j}{p^2_{\text{T,jet}}}} \frac{d\left(\sum_{\text{jets}} \sum_{i \neq j} \frac{E_i E_j}{p^2_{\text{T,jet}}}\right)}{\text{d}\ (\Delta R)}$$

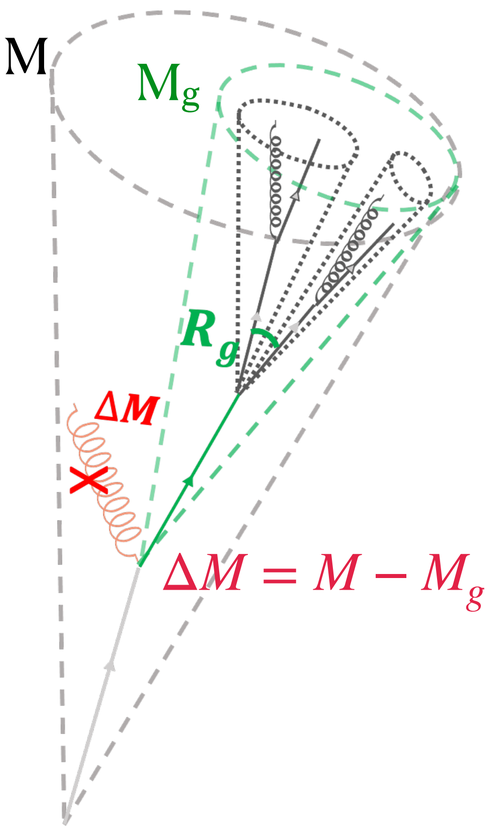
Transition region at $\Delta R \times p_T^{jet} \sim 2 - 3$ GeV independent on jet energy

→ Confinement of quark/gluon degrees of freedom into hadrons occurs at universal momentum scale

Isolating non-perturbative contribution in vacuum shower

Reconstruct jet; then groom to isolate non-perturbative part of shower



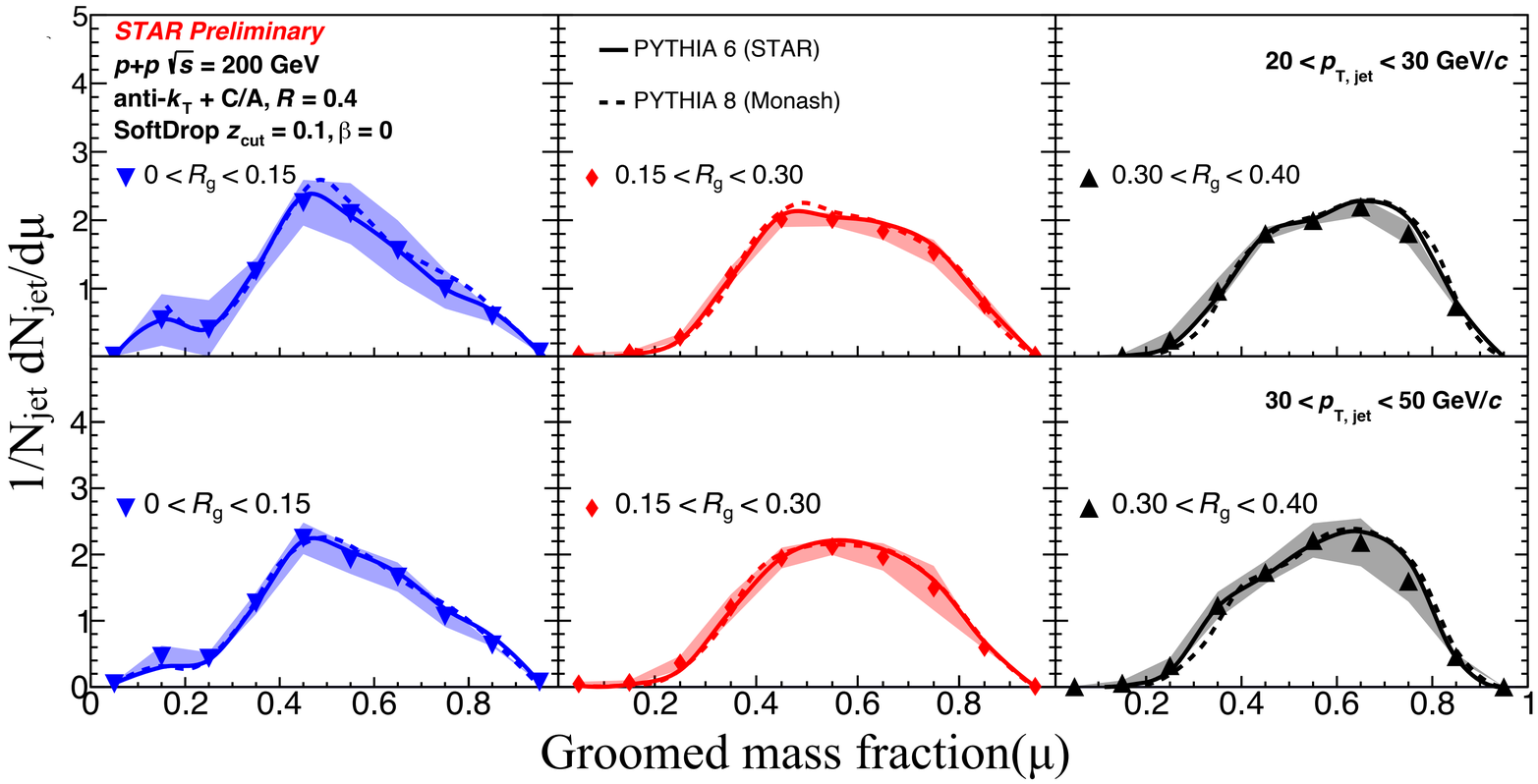


Monika Robotková
30 Mar, 9.00

Anti-correlation between collinear dropped jet mass ΔM/M and R_g
→ consistent with angular ordering of the parton shower

How groomed mass fraction varies with splitting angles?

Monika Robotková
30 Mar, 9.00

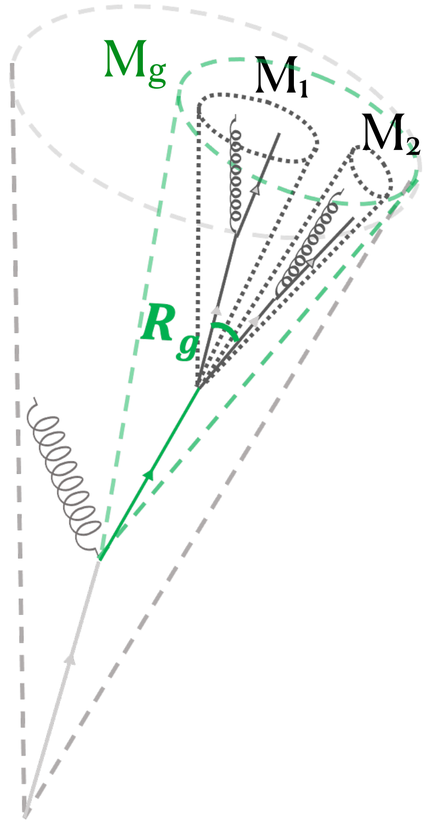


Groomed mass fraction

$$\mu \equiv \frac{\max(M_1, M_2)}{M_g}$$

$$\mu \in [0,1]$$

With SoftDrop condition
$z_{cut} = 0.1$ and $\beta=0$



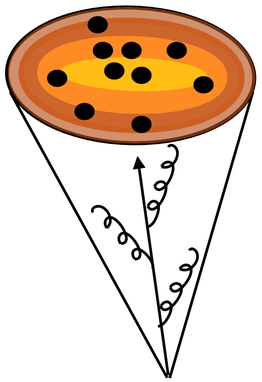
Shift of μ to smaller values at smaller angles indicates a faster reduction of virtuality in the jet shower

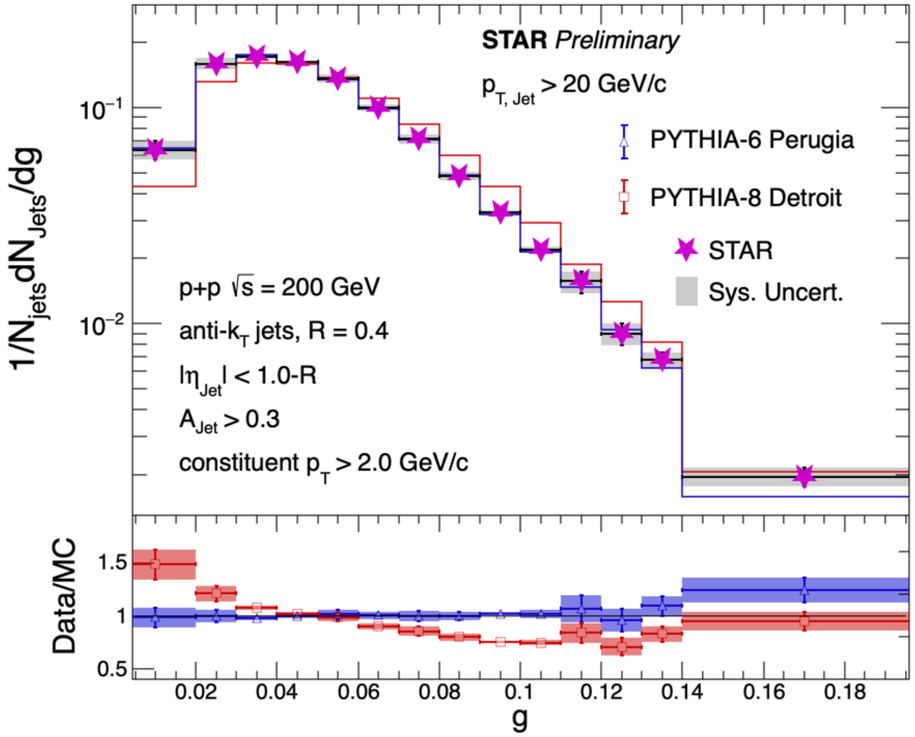
Model vs. data : jet shapes and hadronization

Girth $g = \dfrac{\sum_{\text{trks}} p_{\text{T,trk}}(\Delta R)}{p_{\text{T,jet}}}$

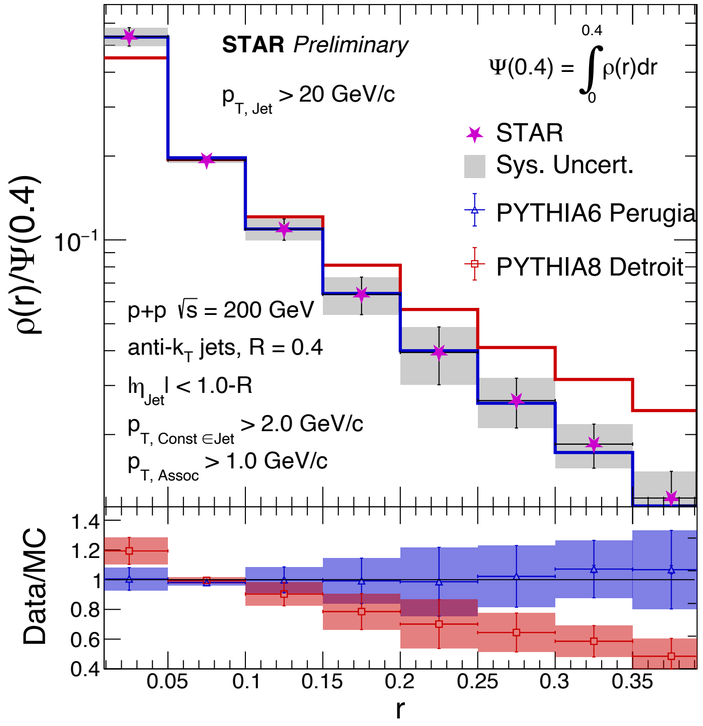
Differential Jet Shapes $\rho(\text{r}) = \dfrac{1}{\delta r}\dfrac{1}{N_{\text{jets}}}\sum_{\text{jets}}\dfrac{\sum_{r^{\text{trk}}\in(r-\delta r/2,\,r+\delta r/2)} p_{\text{T,trk}}}{p_{\text{T,jet}}}$

Tanmay Pani
28 Mar, 11.10

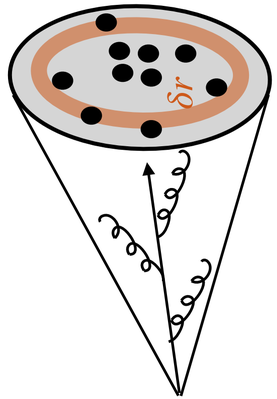




Girth



Radius



Data agree with PYTHIA6 Perugia tune; PYTHIA-8 Detroit needs further tuning

1. Probing fundamental QCD: theory vs reality

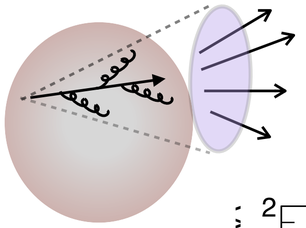
Energy-energy correlations and jet substructure

2. What do hard probes tell us about QGP?

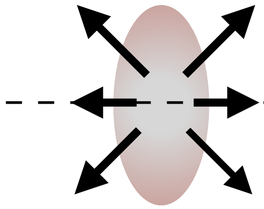
System size dependence of jet and heavy-flavor production and flow

Different manifestations of jet-medium interaction and their consequences

Isobar data: hadron R_{AA} and jet v_2

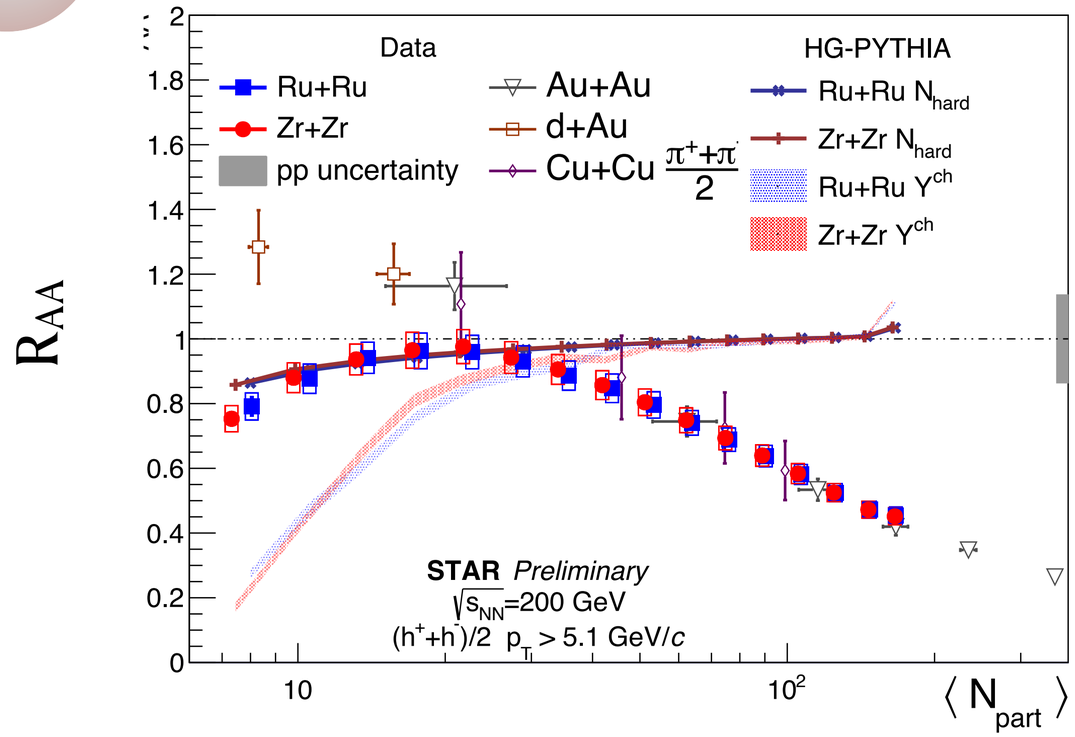


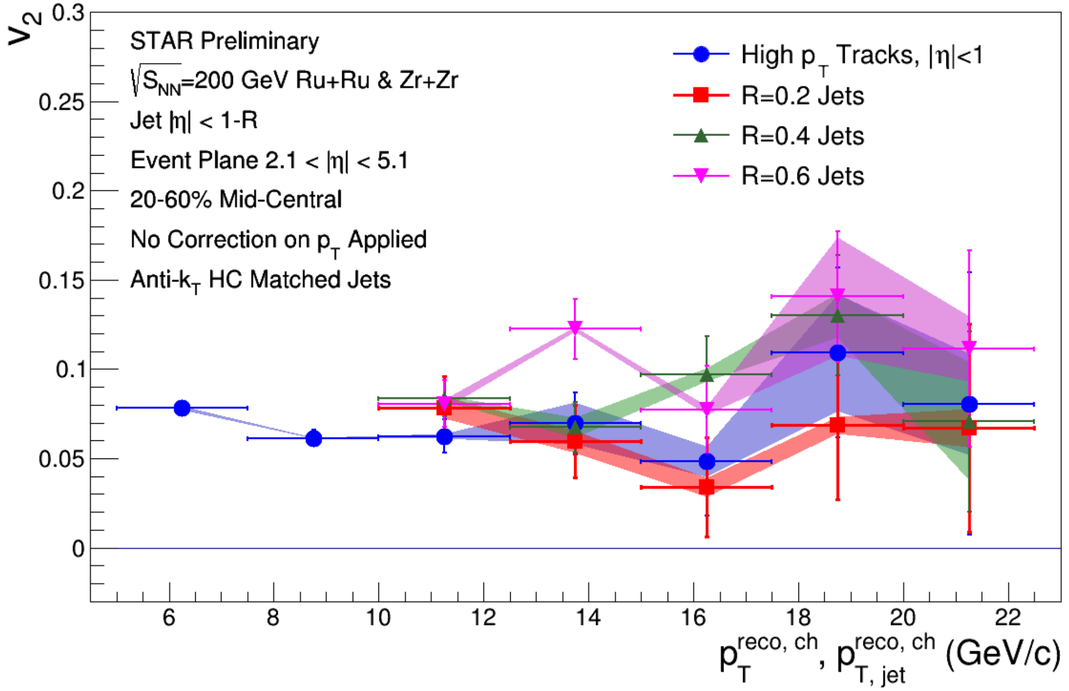
Inclusive hadron suppression



$v_2 = \langle \cos(2(\phi - \psi_2)) \rangle$

Talk: Tristan Protzman
29 Mar, 15.00
Poster: Isaac Mooney





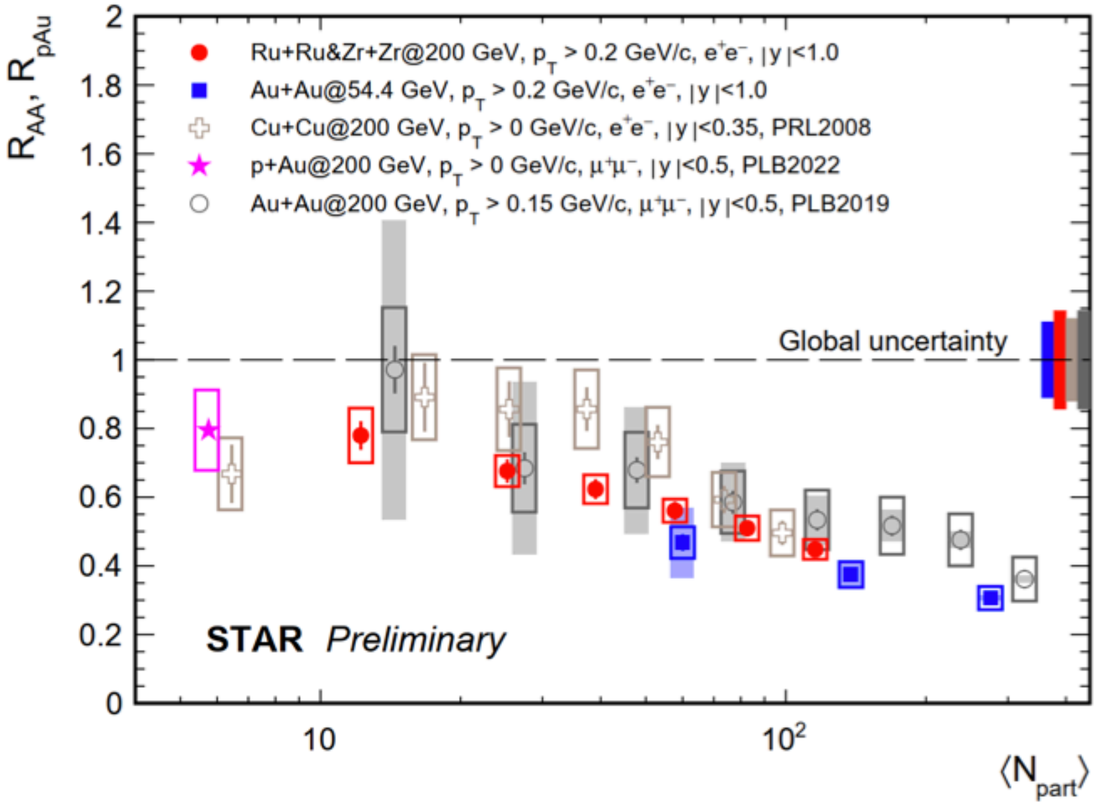
Similar R_{AA} suppression at comparable $\langle N_{part} \rangle$
→ Energy density rather than initial geometry dominates average jet energy loss

High-p_T jet shows non-zero v_2;
no jet R dependence

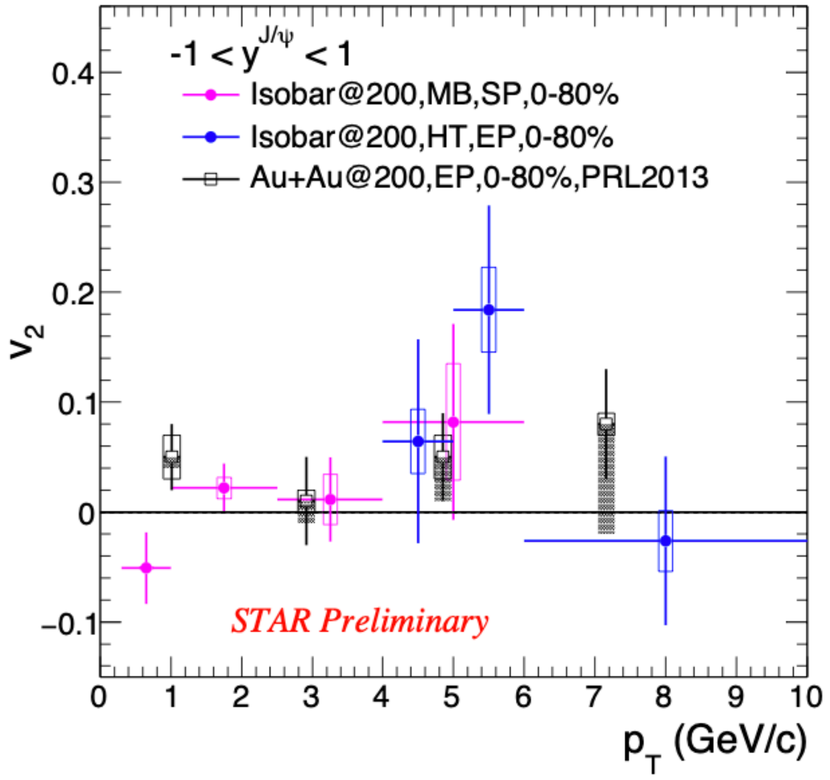
Isobar data: J/ψ R_{AA} and v_2

Highest precision J/ψ measurement at RHIC energies to date

Yan Wang
30 Mar, 10.00



No significant collision system and energy dependence at similar <N_{part}> ;
But strong suppression as in Au+Au



No significant J/ψ v_2 is observed

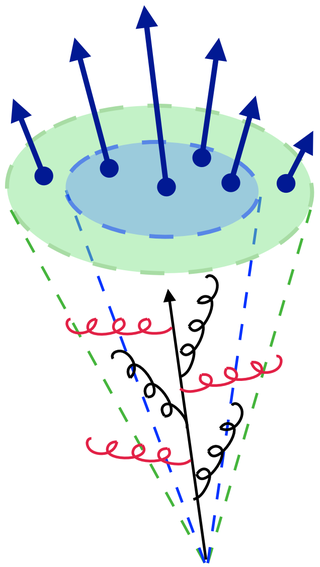
Indication of small regeneration effect and/or small charm quark flow in Isobar?

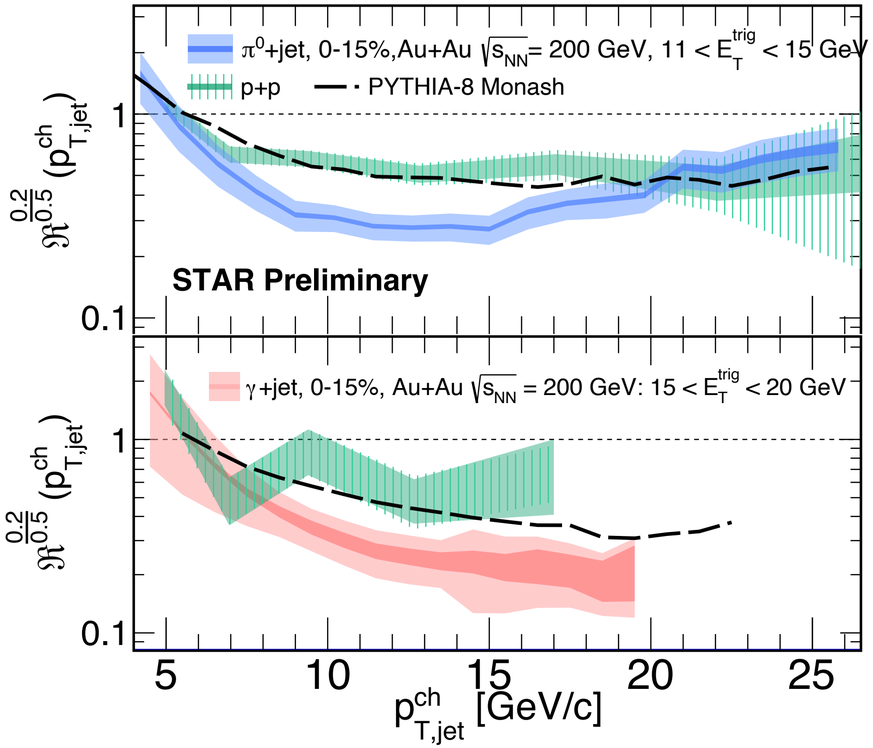
Au+Au data: probing the jet-medium interaction

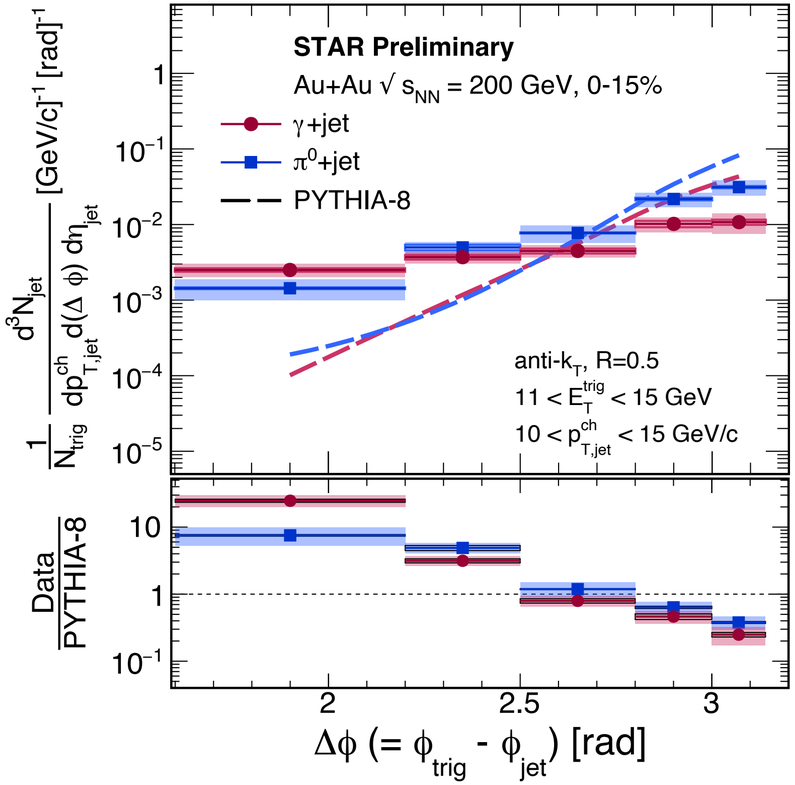
$$\mathfrak{R}^{\frac{\text{small-R}}{\text{large-R}}} = \frac{\Upsilon(p_{T,jet}^{ch})^{\text{small-R}}}{\Upsilon(p_{T,jet}^{ch})^{\text{large-R}}}$$

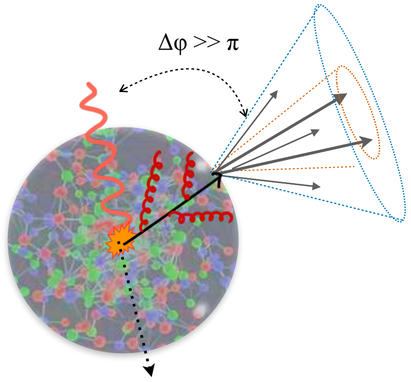
Semi-inclusive γ+jet and π^0+jet measurement

Yang He
30 Mar, 9:40









In-medium intra-jet broadening

→ Disentangle vacuum shower and in-medium radiation

Large off-axis jet yield (acoplanarity) in Au+Au

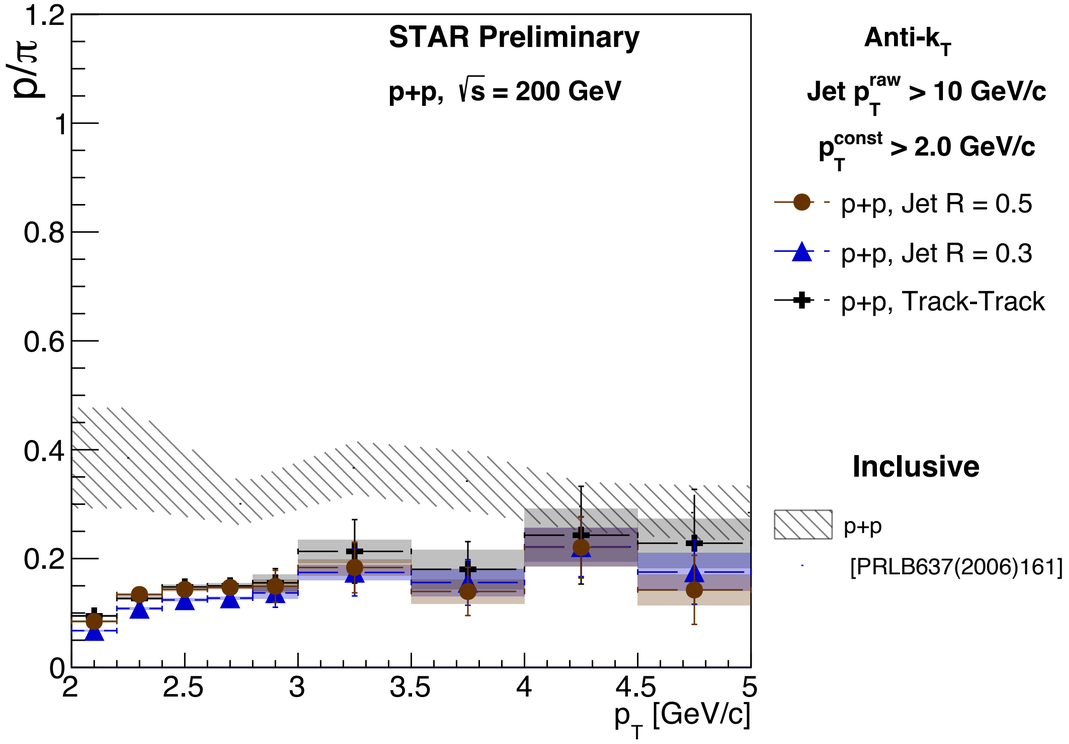
→ In-medium jet scattering?

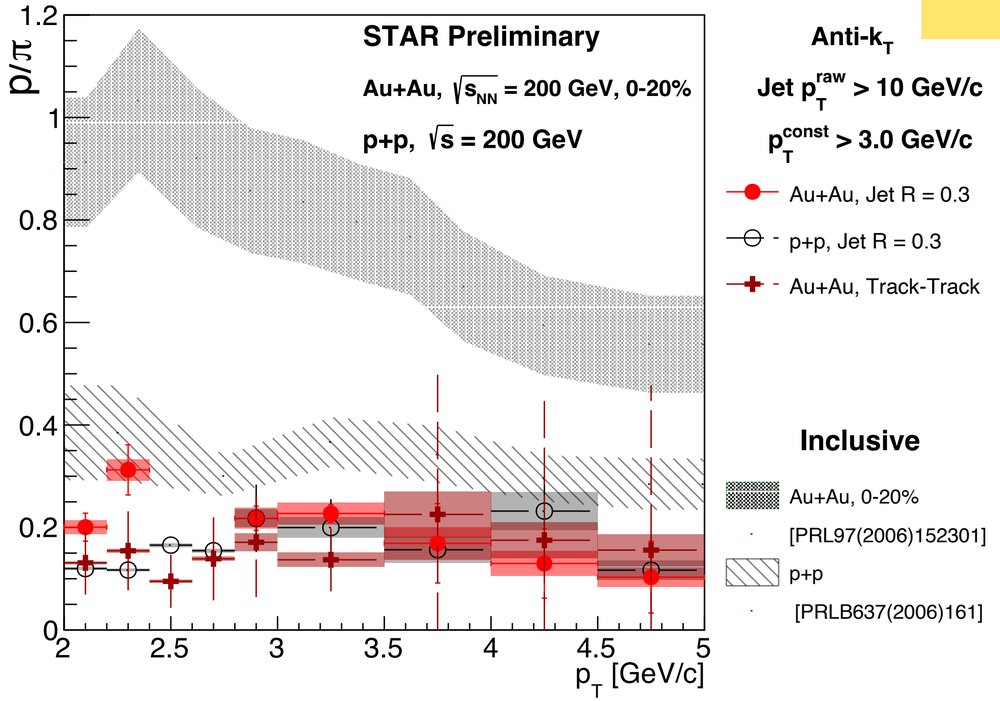
→ Medium response?

Au+Au data: Jet chemistry in the QGP

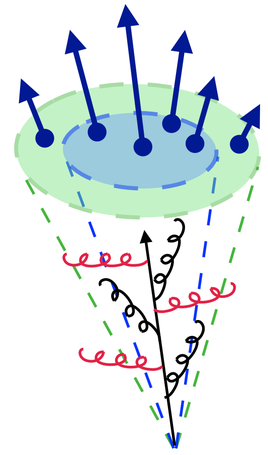
First baryon-to-meson ratio measurement inside a jet at RHIC

Gabriel Dale-Gau
28 Mar, 15.40





$$\frac{p + \bar{p}}{\pi^+ + \pi^-}$$



In medium

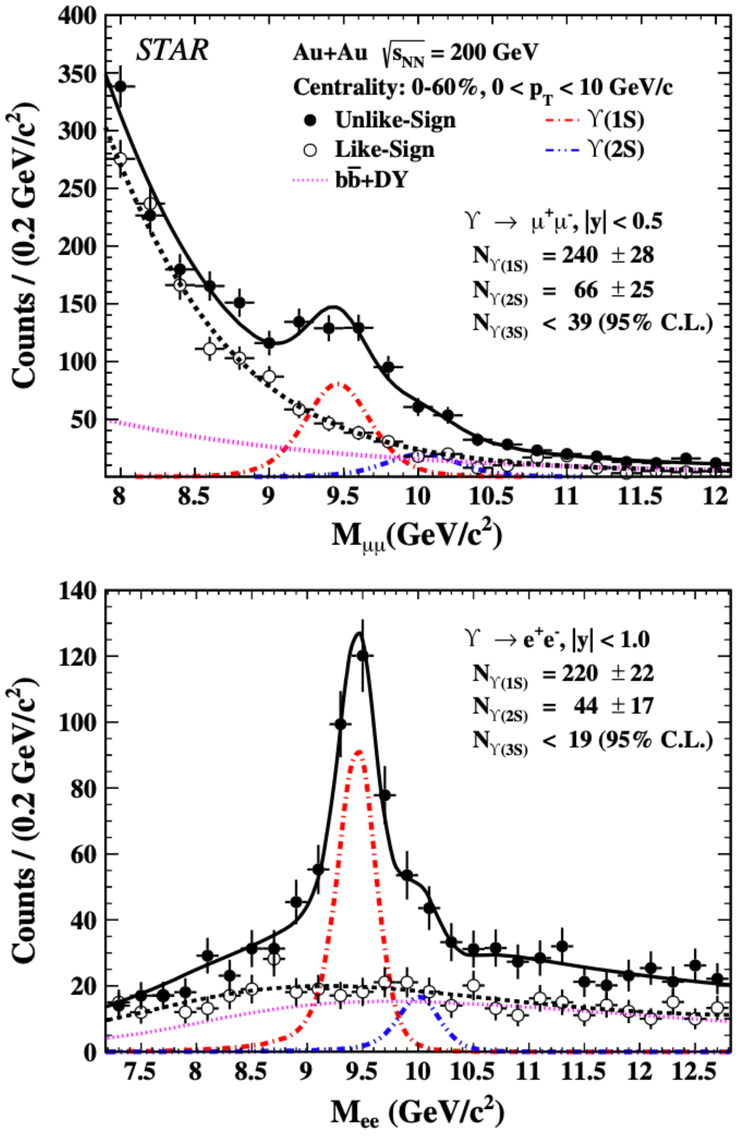
- Strong preference of π over proton production in p+p jets
- Similar p/π ratio in Au+Au and p+p with hard core jet selection with constituent p_T > 3.0 GeV/c

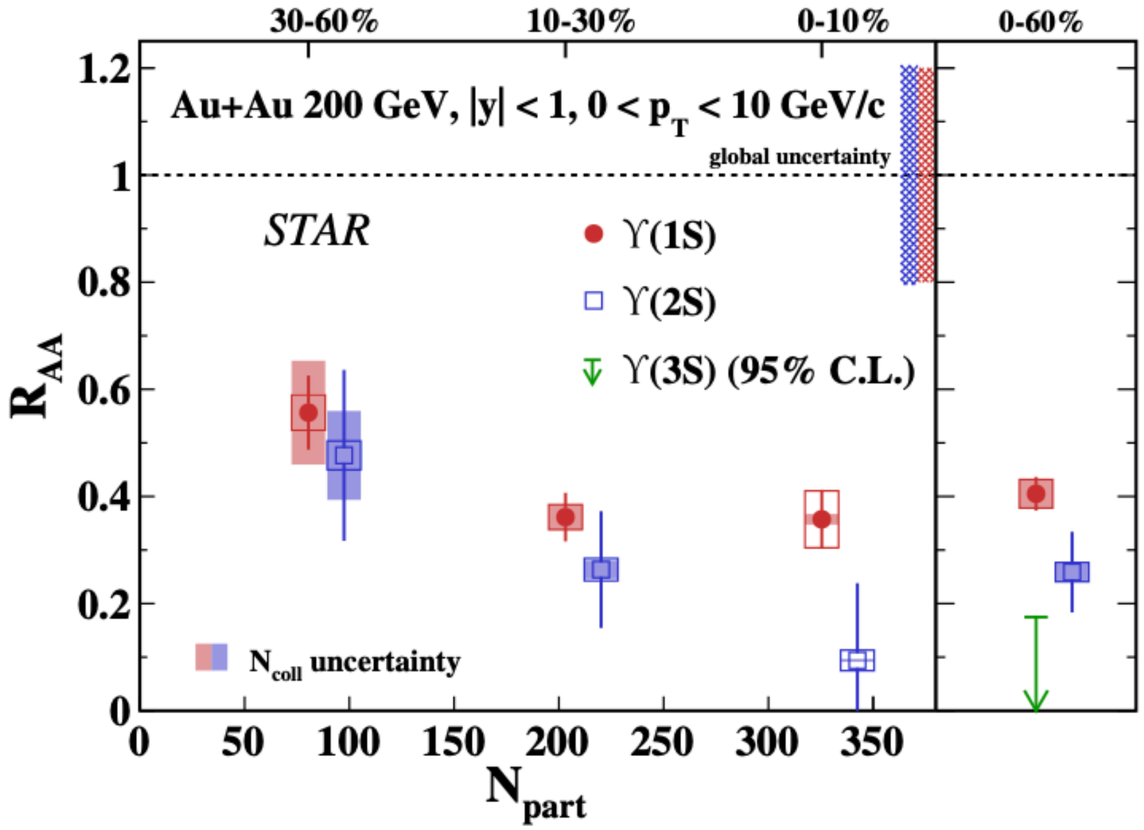
Can jet-medium interaction modify jet chemistry?

→ look at p/π ratio at lower p_T (stay tuned)

QGP temperature: sequential Υ suppression

STAR: PRL 130, 112301 (2023)





Υ(2S) and Υ(3S) significantly more suppressed than Υ(1S)

Sufficient QGP temperature to melt excited Υ states at top RHIC energies

What have we learned?

From QCD in vacuum to hot-dense QCD medium

Big picture

In vacuum (p+p collisions)

Vacuum parton shower sensitive to initial soft-wide angle radiation and a universal scale for parton-hadron transition

→ Interplay between perturbative and non-perturbative QCD

In smaller collision system (isobar collisions)

Same level of jet and J/ψ suppression as seen in Au+Au collisions at similar $\langle N_{part} \rangle$; Non-zero jet anisotropy (v_2); but zero J/ψ v_2 in isobar collisions

→ Are parton energy loss and flow sensitive to initial energy density or collision geometry?

In larger collision system (Au+Au collisions)

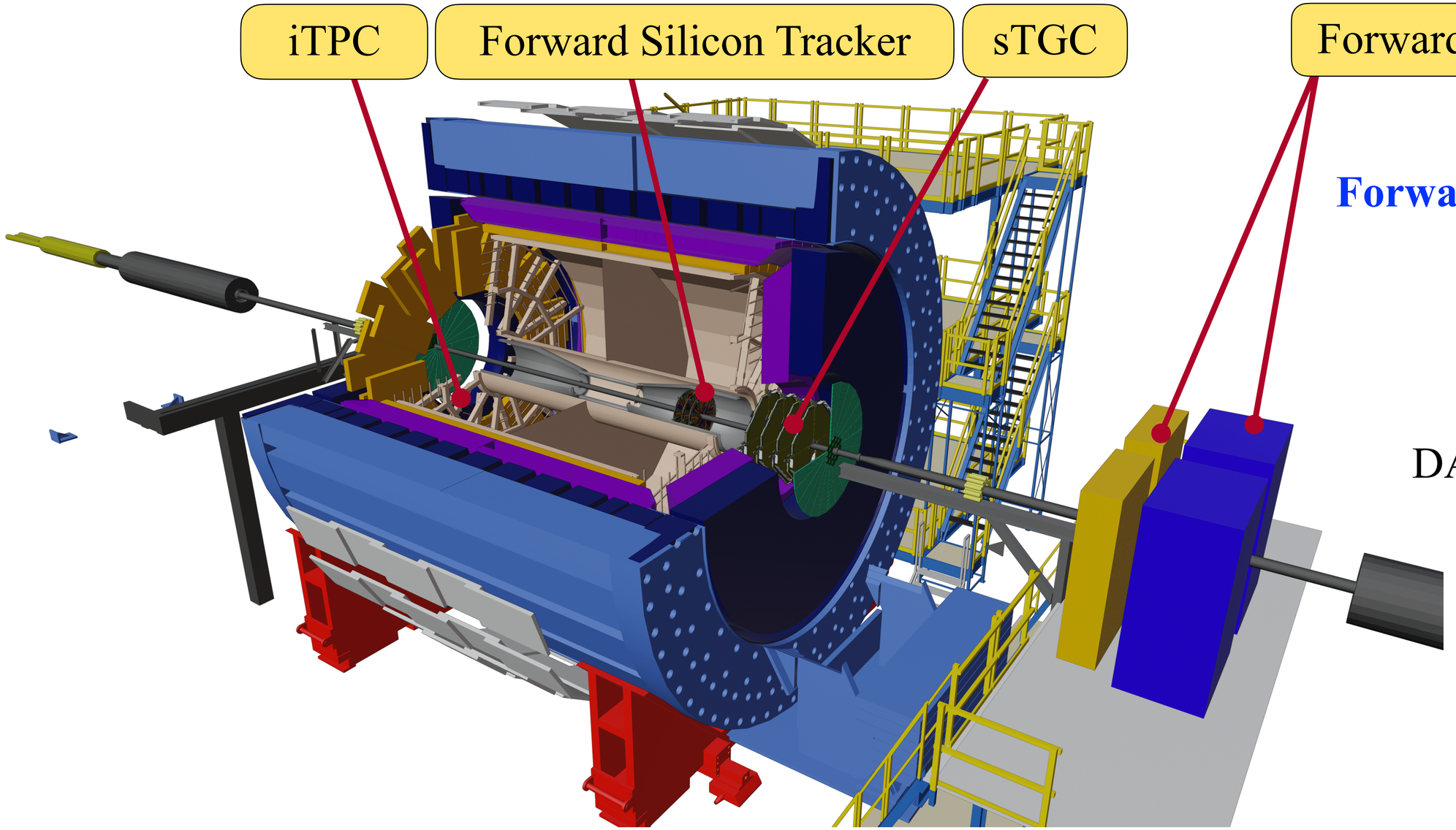
Probe different manifestation of jet-medium interaction (intra-jet broadening, jet suppression, and acoplanarity)

→ Probing the microstructure and dynamics of QGP

STAR continues to explore on these questions in Run23+25…

STAR’s next data taking plan and its physics program

STAR detector with recent upgrades



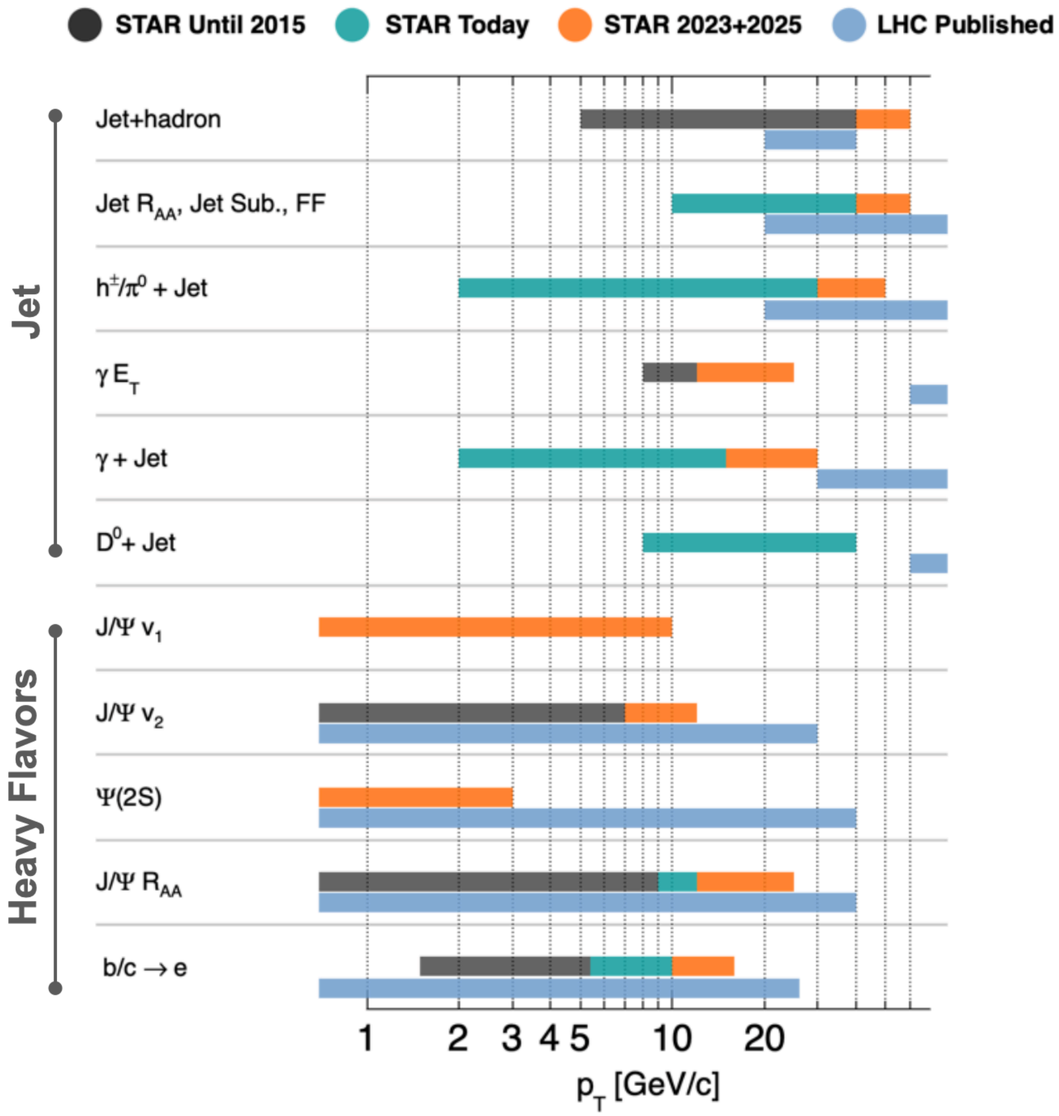
Forward detector upgrade

DAQ rate: 5000 Hz

STAR hard probes physics program

$\sqrt{s_{NN}}$ (GeV)	Species	Number Events/ Sampled Luminosity	Year
200	Au+Au	20B / 40 nb^{-1}	2023+2025
200	p+p	235 pb^{-1}	2024
200	p+Au	1.3 pb^{-1}	2024

Study the microstructure of the QGP
Precision jet and heavy-flavor measurements



STAR BUR-2022:
https://indico.bnl.gov/event/15148/attachments/40846/68609/STAR_BUR_Runs23_25___2022 (1).pdf

STAR presentations

Oral presentations:

1. ***Tanmay Pani:*** *Jet shape observables in p+p and Au+Au collisions at* $\sqrt{s_{NN}}$ *= 200 GeV at STAR* ***[28 Mar, 11.10]***
2. ***Monika Robotkova:*** *Systematic exploration of multi-scale jet substructure in p+p collisions at* $\sqrt{s_{NN}}$ *= 200 GeV by the STAR experiment* ***[30 Mar, 9.00]***
3. ***Gabriel Dale-Gau:*** *Measurements of Baryon-to-Meson Ratios in Jets in Au+Au and p+p Collisions at* $\sqrt{s_{NN}}$ *= 200 GeV by STAR* **[28 Mar, 15.40]**
4. ***Yang He:*** *Measurements of semi-inclusive γ+jet and hadron+jet distributions in heavy-ion collisions at* $\sqrt{s_{NN}}$ *= 200 GeV with STAR* **[30 Mar, 9:40]**
5. ***Tristan Protzman:*** *Medium effects on Hadrons and Jets in* $\sqrt{s_{NN}}$ *= 200 GeV Isobar collisions at STAR* ***[29 Mar, 15.00]***
6. ***Yan Wang:*** *J/ψ production in Ru+Ru and Zr+Zr collisions at* $\sqrt{s_{NN}}$ *= 200 GeV with the STAR experiment* ***[30 Mar, 10.00]***
7. ***Andrew Tamis:*** *Measurement of two-point energy Correlators within jets in p+p collisions at sqrt(s) = 200 GeV* ***[29 Mar, 15.00]***

Poster presentations:

1. ***Priyanka Roy Chowdhury:*** *Femtoscopic correlations of* D^0 *seasons with identified hadrons in Au+Au collisions at* $\sqrt{s_{NN}}$ *= 200 GeV at STAR*
2. ***Brennan Schaefer:*** *Measurement of the event multiplicity dependence of J/ψ production in p+p collisions at* $\sqrt{s}$ *= 500 GeV with STAR at RHIC*
3. ***Isaac Mooney:*** *Nuclear modification of charged hadrons and jets in isobar collisions at √sNN = 200 GeV at STAR*

Thank you!